REMARKS

Claims 17-19 have been amended to correct for a lack of antecedent basis. Upon entry of the Amendment, which is respectfully requested, Claims 7-19 and 21-25 will be pending, with Claims 7-16 being withdrawn from consideration.

Response to Rejection Under 35 U.S.C. §112

Claims 17-19 and 21-25 are rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

Applicant has reviewed the Examiner's rejection, and amended the claims to correct for the lack of antecedent basis. Accordingly, withdrawal of the rejection is requested.

Response to Rejections Under § 103

Claims 17, 19, 21 and 25 are rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over EP 0751567 to Andricacos et al. ("EP '567") in view of U.S. Patent Application Publication No. 2003/0217462 to Wang et al. ("Wang"), and further in view of U.S. Patent Application Publication No. 2003/0116845 to Bojkov et al. ("Bojkov"). Applicant respectfully traverses the rejection.

Bojkov discloses a solder bump structure having a barrier metal layer at the interface between the Cu layer and the solder. As shown in the attached Fig. A, The barrier metal layer has a double layer structure comprised of a first barrier layer (407a) and a second barrier layer (407b). The first barrier layer is selected from titanium (Ti), tantalum (Ta), tungsten (W), or

alloys thereof to getter oxygen in the Cu layer. *See*, paragraph [0036]. Further, a second barrier layer made of nickel vanadium (NiV) is deposited to prevent external diffusion of Cu. Id.

Bojkov further discloses that the oxygen in the Cu layer is gettered by the first barrier layer, and thus a good ohmic contact can be realized. *See*, paragraph [0036]. Applicant respectfully submits that since the oxygen in the Cu layer is gettered by the first barrier layer, the first barrier layer itself is oxidized. That is, in Bojkov, the barrier metal at the Cu/barrier metal interface is oxidized.

In contrast, according to the present invention, oxygen in the Cu layer is gettered by an impurity containing oxygen gettering layer formed on the Cu. Therefore, the barrier metal (Ta) being an underlayer of the Cu layer is not oxidized. Further, since the impurity containing oxygen gettering layer formed on the surface of the Cu layer is removed using a chemical/ mechanical polishing technique or the like, the layer is not present in the final structure. However, the unoxidized barrier metal (Ta) of the Cu/barrier metal (Ta) interface can be realized in the final structure. *See*, Fig. 16, representing a SIMS analysis demonstrating that no oxygen peak exists at the Cu/barrier metal interface.

As described above, and set forth in the attached Fig. B, Bojkov discloses that the barrier metal of the Cu/barrier metal interface is oxidized, while in the present invention, the barrier metal of the Cu/barrier metal interface is not oxidized. Thus, Applicant respectfully summits that Andricacos, Wang and Bojkov fail to disclose or suggest the present invention. Accordingly, withdrawal of the rejection is respectfully requested.

Claim 18 is rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over Andricacos in view of U.S. Patent No. 5,552,341 to Lee, and further in view of Bojkov.

Claims 22-24 are rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over Andricacos in view of Wang, further in view of Bojkov, and still further in view of Lee.

Applicant respectfully traverses the rejections based on the discussion below and the differences shown in the attached Fig. C.

Lee concerns grain boundary segregation of oxides. Specifically, Lee discloses grain boundaries of the barrier metal, the effect of which is to suppress the main wiring material, Al, from being diffused to the outside (silicon substrate) through the barrier metal, thereby causing junction leakage.

In contrast, the present invention relates to grain boundaries of the main wiring material, and aims to improve wiring reliability. Specifically, the present invention seeks to improve the electromigration resistance and stress migration resistance by a suppressing the grain boundary diffusion of the main wiring material itself. Further, the present invention has an oxidation suppressing effect on the barrier layer. Accordingly, Applicant respectfully submits that one would not have expected the effects of the present invention from the cited art.

In addition, contrary to the Examiner's assertion that Lee is applicable to grain boundaries of all metals, Applicant respectfully submits that it is well know in the art that the teachings of Lee are not applicable to grain boundaries of all metals. Specifically, it is well known:

1. that there is a phenomenon of corrosion cracking generated as a result of oxidation of specific elements at the grain boundary; and

2. that Ti, Nb, and Al impurities form metal oxide particles which cause metal fatigue.

As evidence of the phenomenon of corrosion cracking, Applicant respectfully sets forth below an English language translation of an excerpt from "Frontier of Materials Engineering and Prospect of Maintenance Technology for Nuclear Power Plants." A copy of the paper, which can be found at http://www.jnes.go.jp/event/symposium05fin/img/2-2.pdf, is attached for the Examiner's convenience and includes marking showing the excerpted text.

"2. Stress Corrosion Crack Growth Mechanism

Stress corrosion cracking is, as is well known, a phenomenon generated under a combination of material, environment, and dynamics, and the diversity of involved factors complicates the problem. Particularly, as factors influencing crack generation are extremely diverse, it has been known that a slight difference in conditions including uncertainty of the crack generating position causes a great difference in results, and many challenges still remain for a quantitative prediction including a statistical analysis thereof. Meanwhile, when consideration is limited to crack growth, all possible phenomena have generally occurred at a crack tip where on the spot intensity is uniquely defined by a stress intensity factor, which is a fracture mechanics parameter, and it would not be an exaggeration to say that grasping the phenomena that occur there is all. Phenomena that have occurred at a crack tip are schematically summarized in FIG. 1. This features phenomena that occur in an extremely limited region and

environment and in the presence of extremely high dynamic stress/strain field, and according to the results of observation (FIG. 2) through a transmission electron microscope, a crack tip opening has been considered to be probably about 10 nm. According to past studies, the following mechanisms could be mentioned as typical crack growth mechanisms of structural materials in a light-water reactor environment.

FIG. 1: Schematic View of Local Oxidation Kinetics at Crack Tip

FIG. 2: Transmission Electron Microscopic Observation of Stress Corrosion Crack Tip

1) Slip-Dissolution Mechanism: An oxide film at a crack tip is physically broken by a slip deformation, a new surface is formed, and a dissolution reaction rapidly occurs on the surface to cause crack growth. Solution chemistry of the crack tip plays an important role, and concentration of anionic species hinders reformation of a protective film to accelerate crack growth. (This results in a tarnish rupture mechanism when the amount of dissolution is small and the film thickness is large.)

2) Slip-Oxidation Mechanism: A crack tip is covered with an oxide film, and an oxidation reaction rapidly occurs through the film degraded in protection performance by deformation to cause crack growth. Protection performance of the film plays an important role.

3) Internal Oxidation Mechanism: Specific elements on grain boundaries are oxidized by stress-assisted grain boundary diffusion of oxygen atoms to cause crack growth. Trace elements that segregate on the grain boundaries play an important role.

4) Hydrogen-Induced Cracking Mechanism: Hydrogen taken into the material by a reaction at a crack tip, an oxidation reaction in the periphery thereof, or dissolved hydrogen accumulates in the crack tip to cause crack growth."

As evidence that is known that Ti, Nb, and Al impurities form metal oxide particles which cause metal fatigue, Applicant respectfully sets forth below an English language translation of an excerpt from "Laser Ablation (LA)-ICP-MS for Production Control of Nickel Alloys." A copy of the paper, which can be found at http://www.chem-agilent.com/pdf/00059250.pdf, is attached for the Examiner's convenience and includes marking showing the excerpted test.

"Besides intentionally adding alloy elements to obtain useful characteristics not possessed by the original pure Ni material, many other elements exist as alloy pollutants and impurities at trace levels.

Impurity elements uniformly melt in a solid solution alloy matrix or exist as discontinuous crystal grains or fillers, and can possibly have a significant effect on the characteristics of a final product. For example, Ti, Nb and Al impurities form metal oxide particles to induce cracks, shorten life span, and cause metal fatigue. Such impurities that weaken crystal grain boundary bonding performance to lower brittle fracture characteristics include Bi, Te, Se, Pb, and Tl, all have a harmful effect at a content of not more than 100 ppm, and Bi has the maximum effect at the lowest content. Other impurity elements to lower malleability and ductility at a low content include As, Ba, Ca, Li, Mg, Sb, Sn, and Sr. This is probably because these elements have an effect on crystal grain boundary bonding performance."

When such metal fatigue has occurred, the layer no longer functions as a barrier layer. As such, when oxides are formed at metal grain boundaries, the resulting effect differs depending on the type of metal. Thus, Applicant respectfully submits that the teachings of Lee cannot be applied to all metal boundaries. Accordingly, Applicant respectfully submits that Andricacos, Wang, Bojkov and Lee fail to disclose or suggest the present invention, and withdrawal of the rejection is respectfully requested.

In view of the above, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited. If any points remain in issue which the Examiner feels may be best resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

The USPTO is directed and authorized to charge all required fees, except for the Issue Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any overpayments to said Deposit Account.

Respectfully submitted,

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